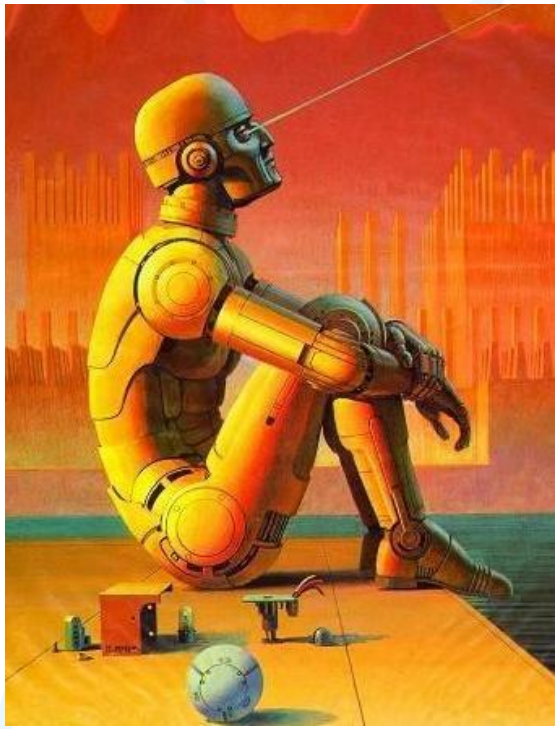
Intelligence-Based Prediction, Compensation and Robust Adaptive Control of UUMSs with Hysteresis Nonlinearity

Pengcheng Liu



Motivations

❖ Uncertain Underactuated Mechanical Systems (UUMSs)

❖ Model imprecision of uncertain systems

- *Structured (parametric) uncertainties*
- *Unstructured uncertainties (unmodelled dynamics, e.g. friction, flexibility, hysteresis, backlash, etc.)*

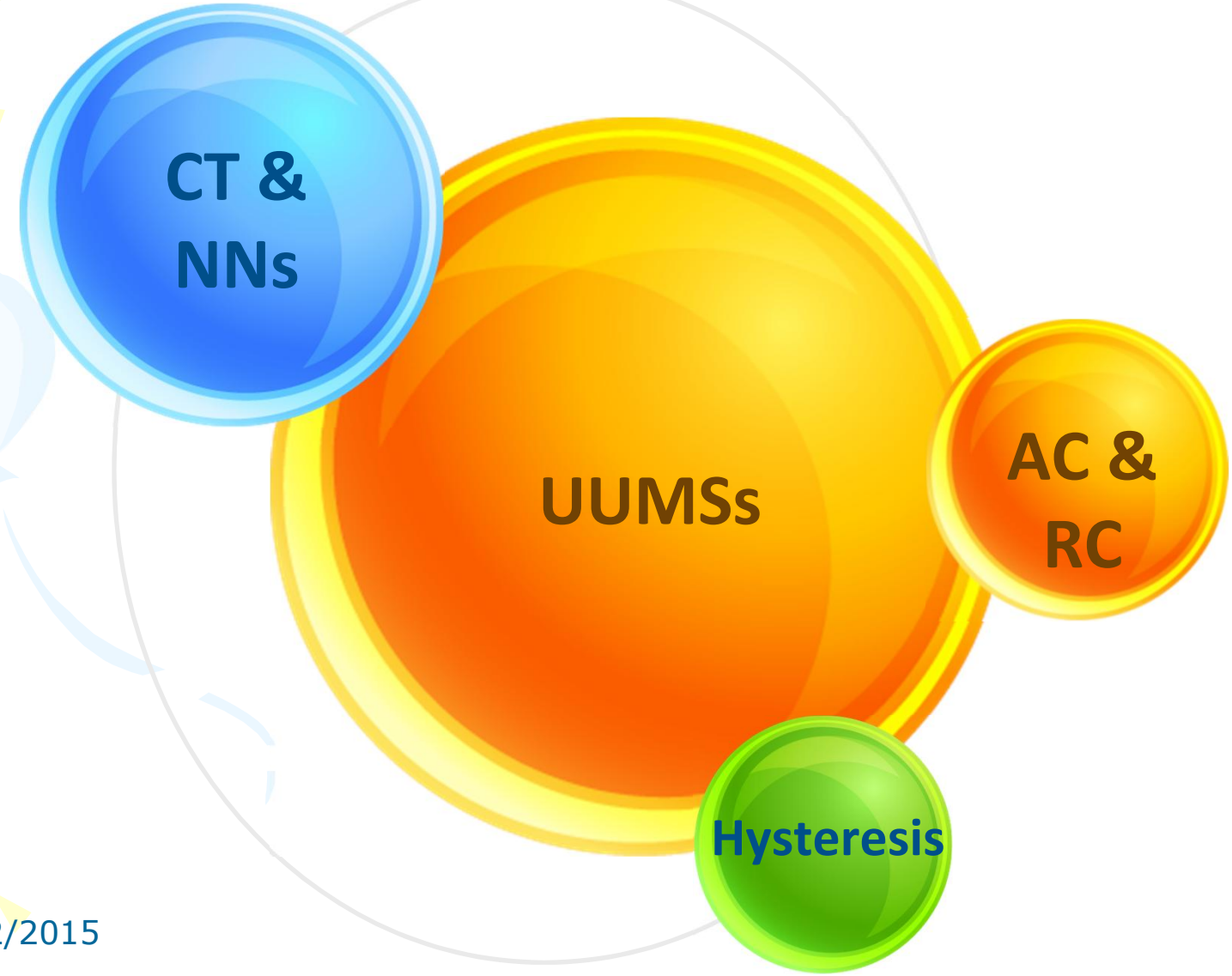
❖ Learning, prediction & adaptation algorithms

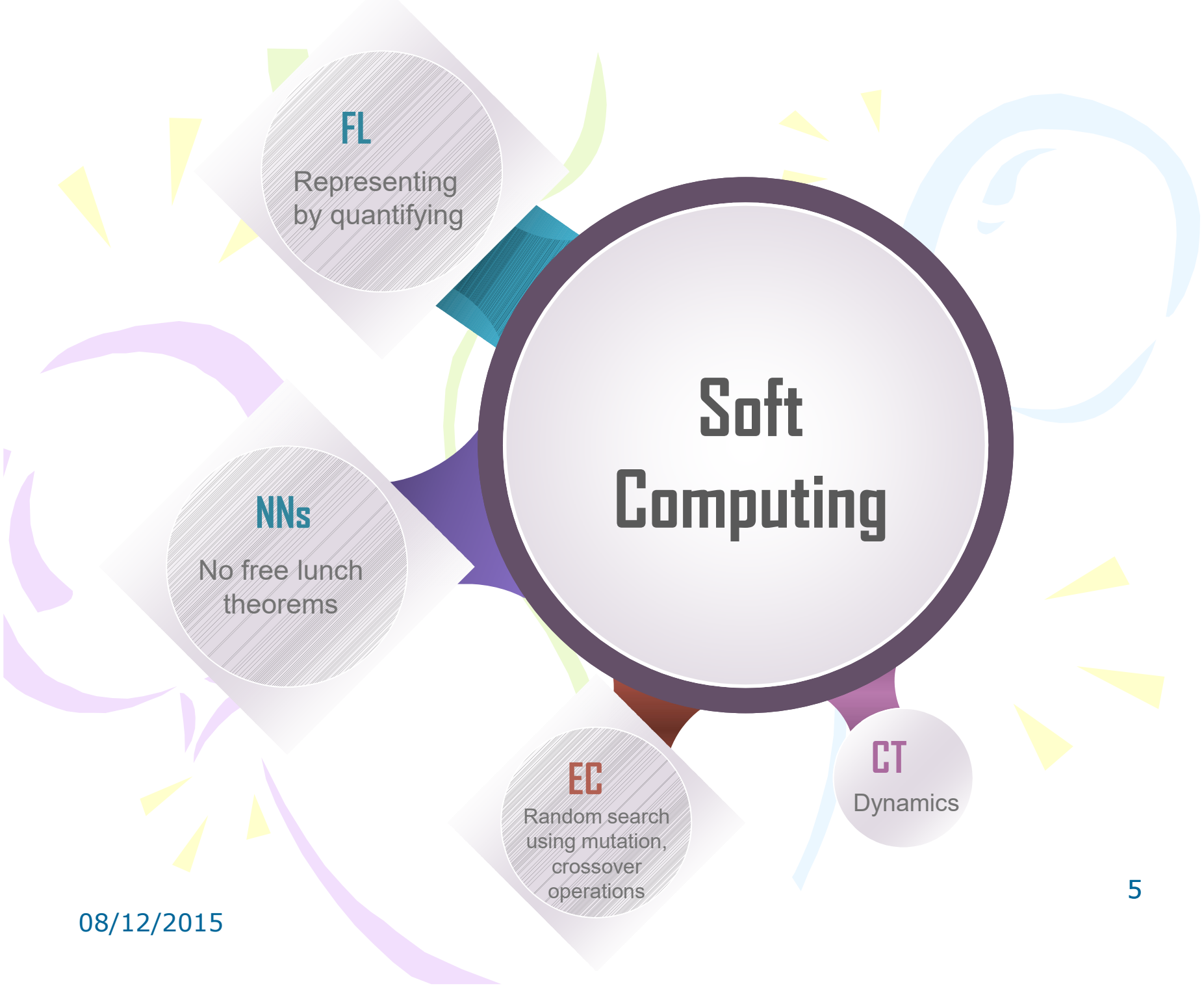
- *Physical systems/processes are inherently nonlinear*

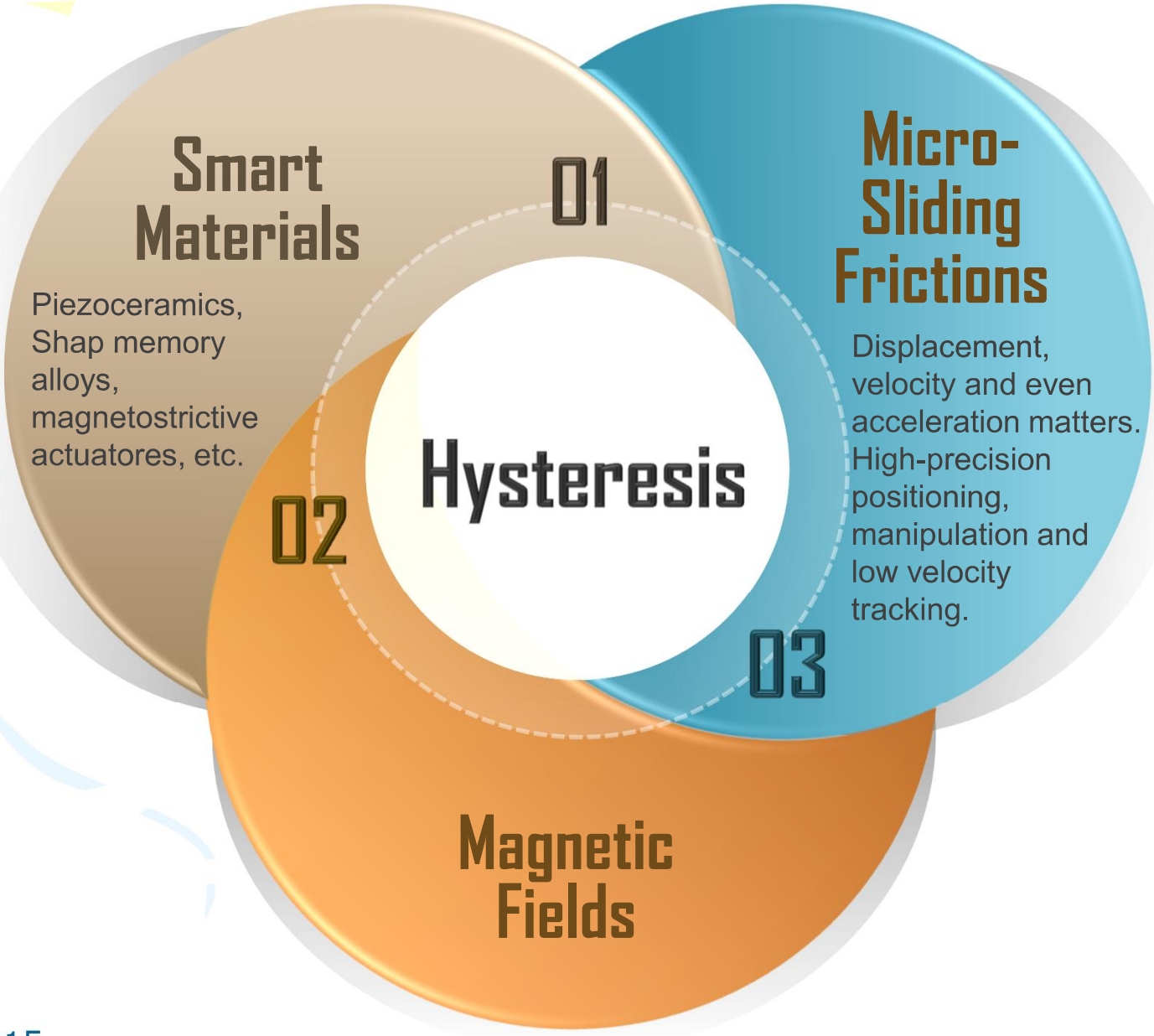
❖ Friction & hysteresis nonlinearities

Intelligence

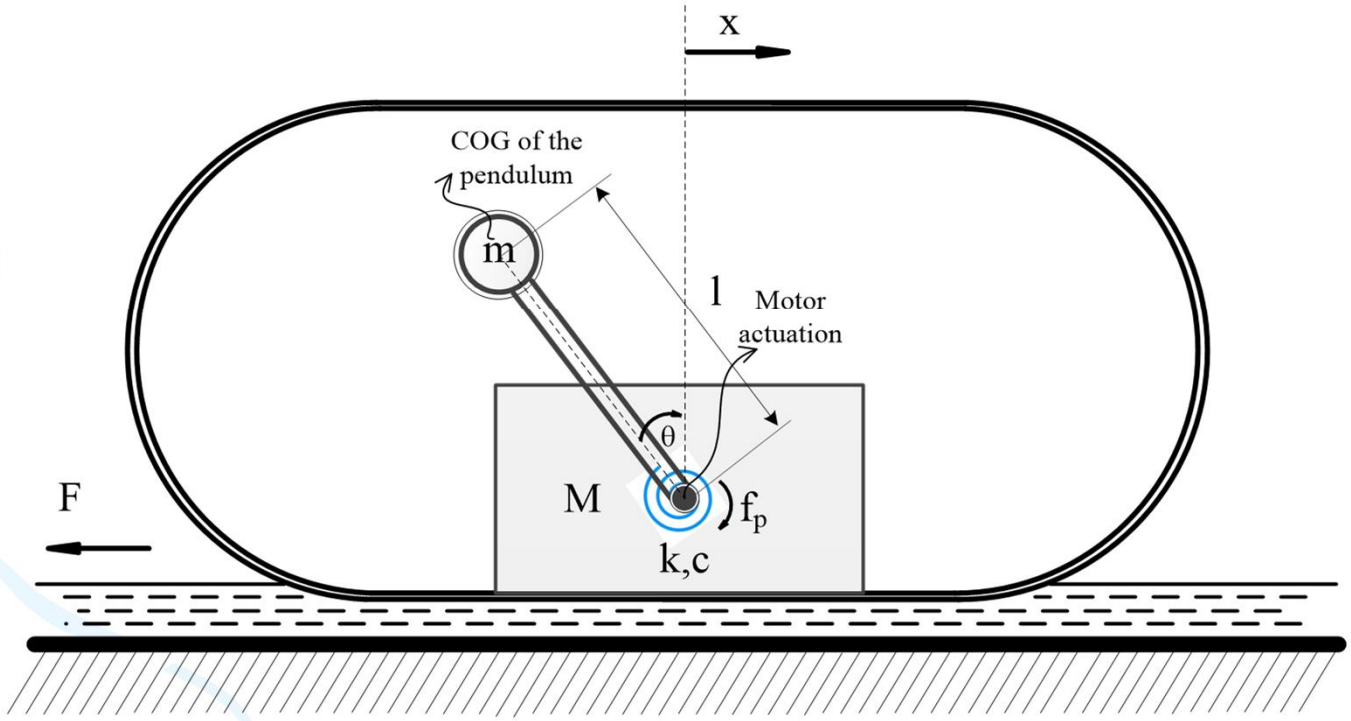
Research Interests




FL
Representing by quantifying
NNs
No free lunch theorems
Soft Computing
EC
Random search using mutation, crossover operations
CT
Dynamics


Smart Materials
01
Piezoceramics, Shap memory alloys, magnetostrictive actuatores, etc.
Micro-Sliding Frictions
Displacement, velocity and even acceleration matters. High-precision positioning, manipulation and low velocity tracking.
02
Hysteresis
03
Magnetic Fields

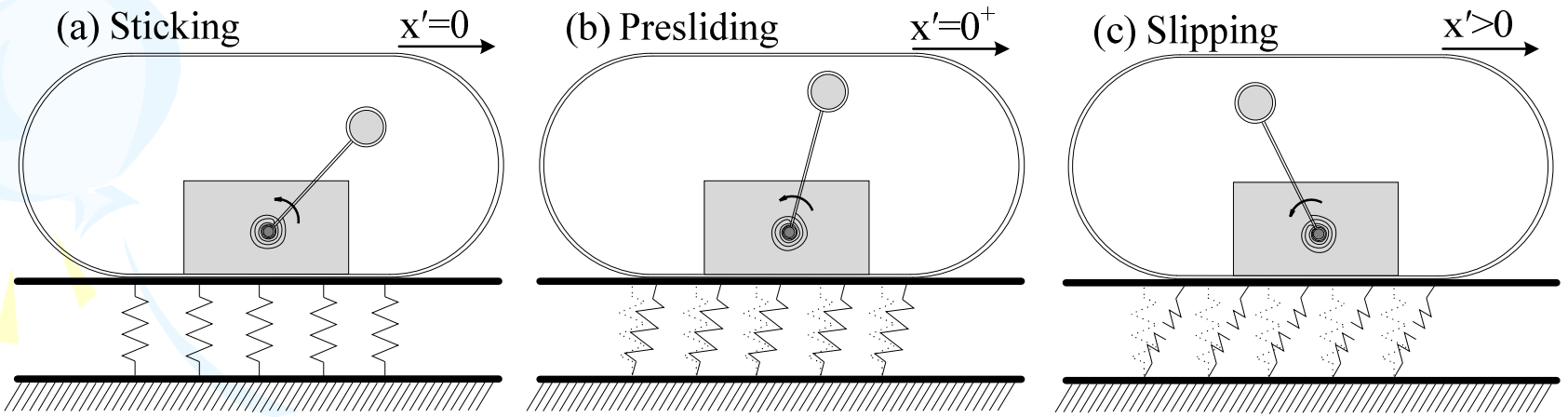
An accurate prediction of hysteresis nonlinearity for the vibro-driven capsule system using chaos theory



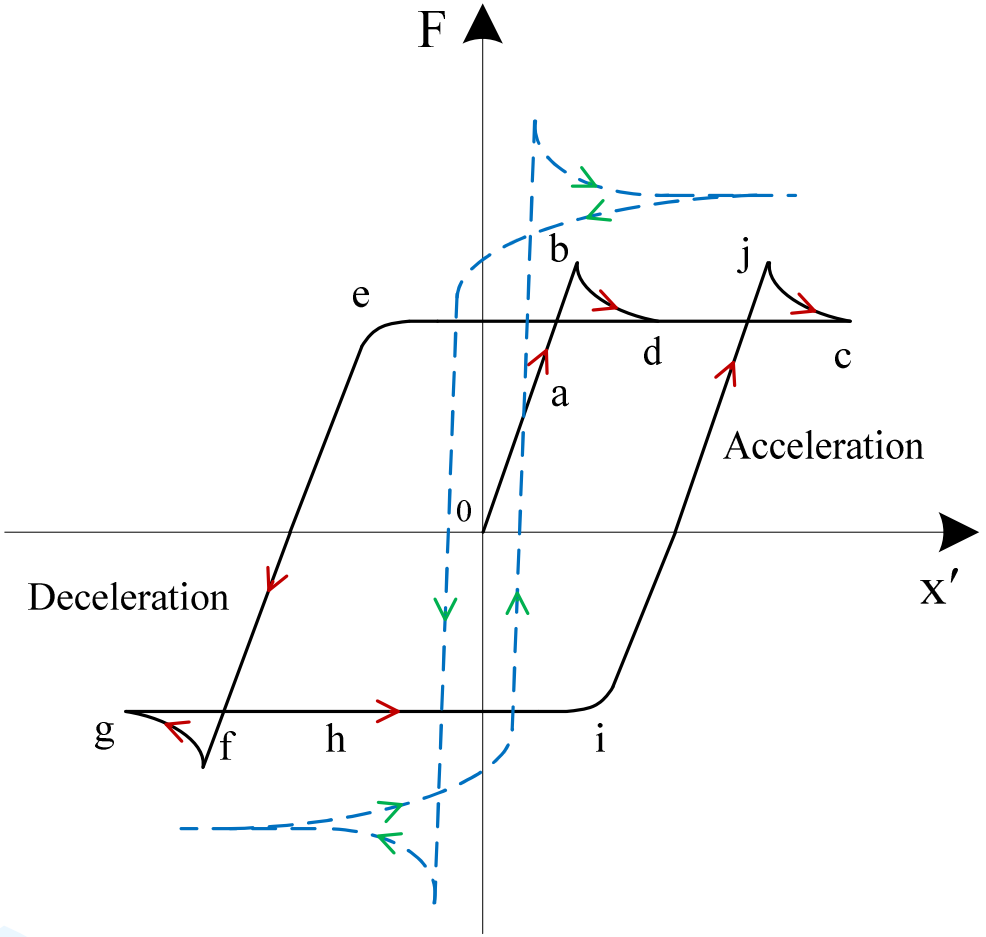
Schematic of the pendulum-driven capsule system

An accurate prediction of hysteresis nonlinearity for the vibro-driven capsule system using chaos theory

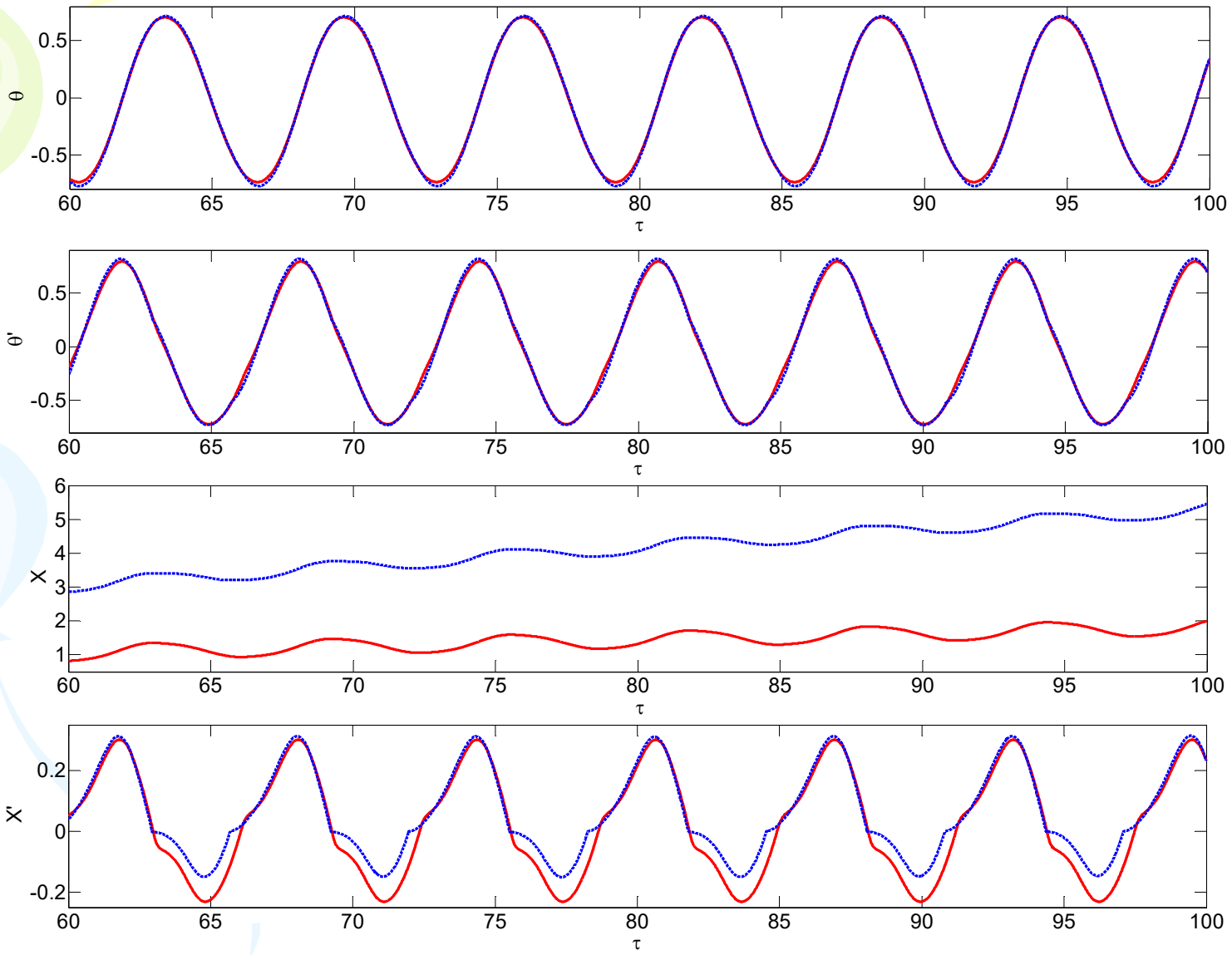
Phenomenological Analysis



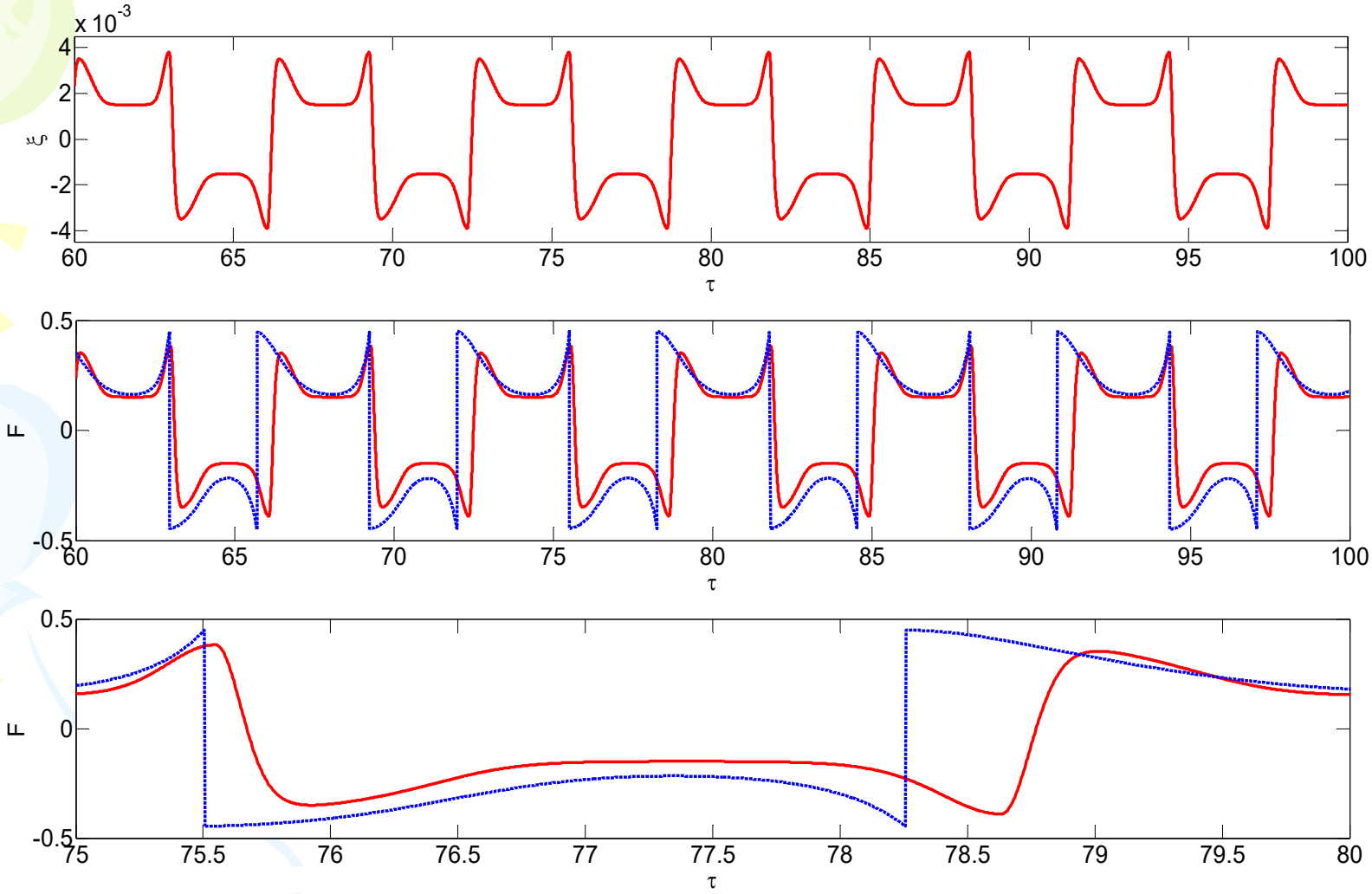
Schematic of the microscopic elastic limit for sticking, presliding and slipping phases



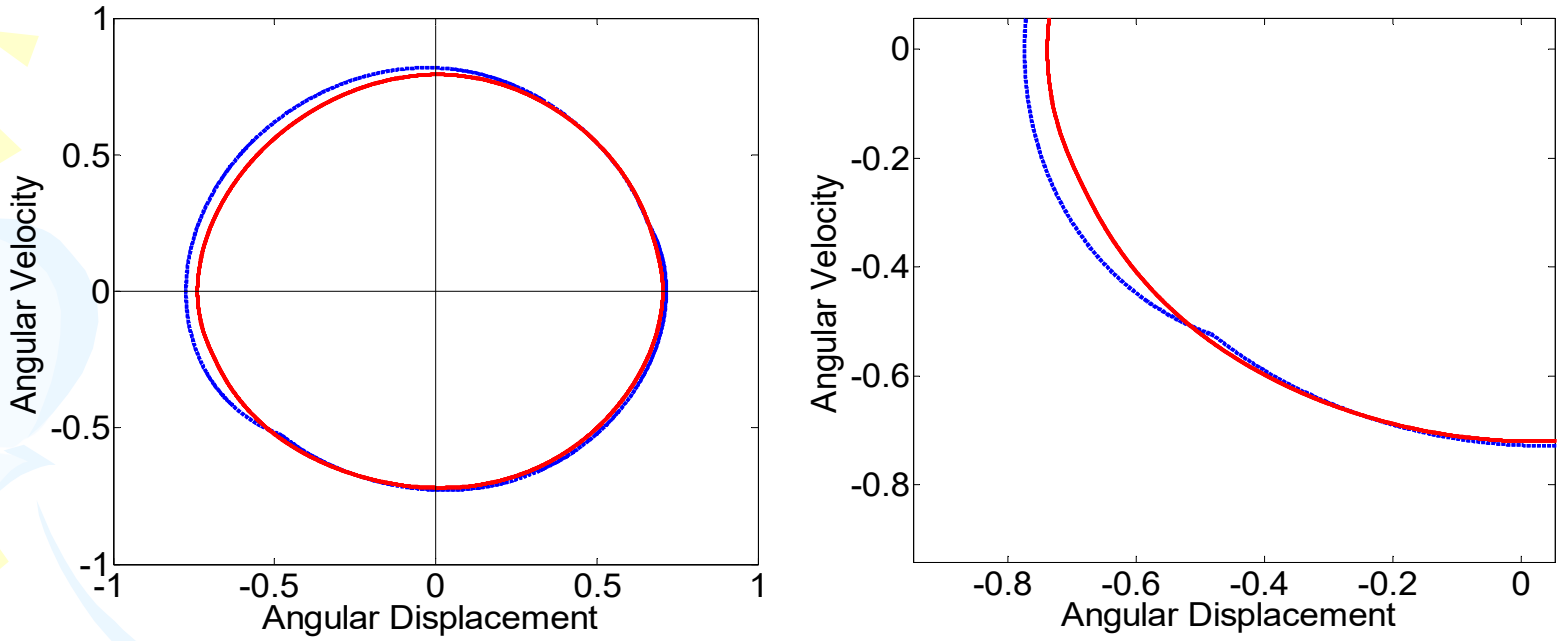
Schematic of the reversible (black solid line) and non-reversible (blue dashed line) characteristics of the friction forces as a function of the relative velocity between two contacting bodies. The directions of the loops are marked by red and green arrows.



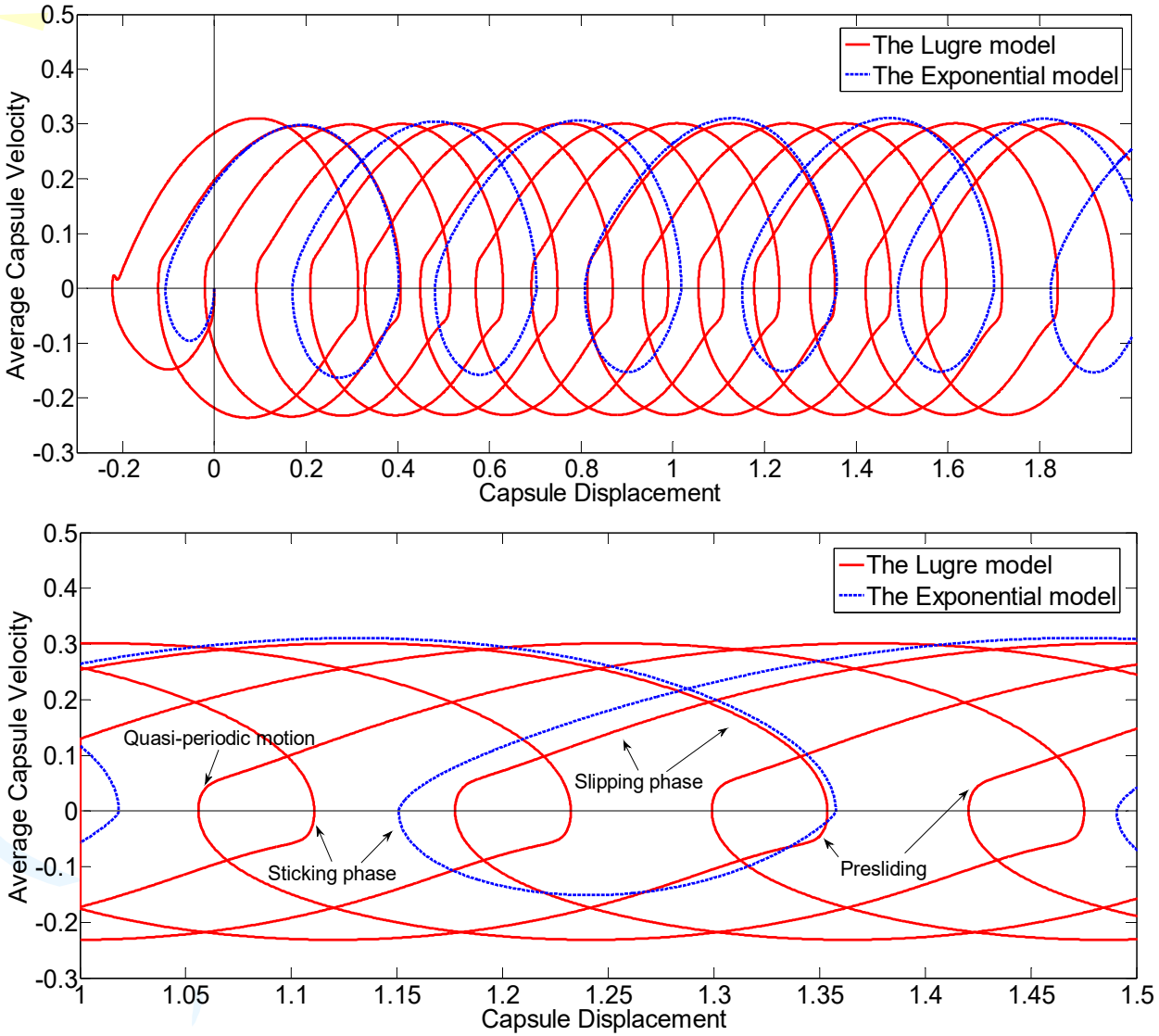
Comparison of the friction-driven response in time coordinate with the LuGre model (red solid lines) and the Exponential model (blue dashed lines), respectively.



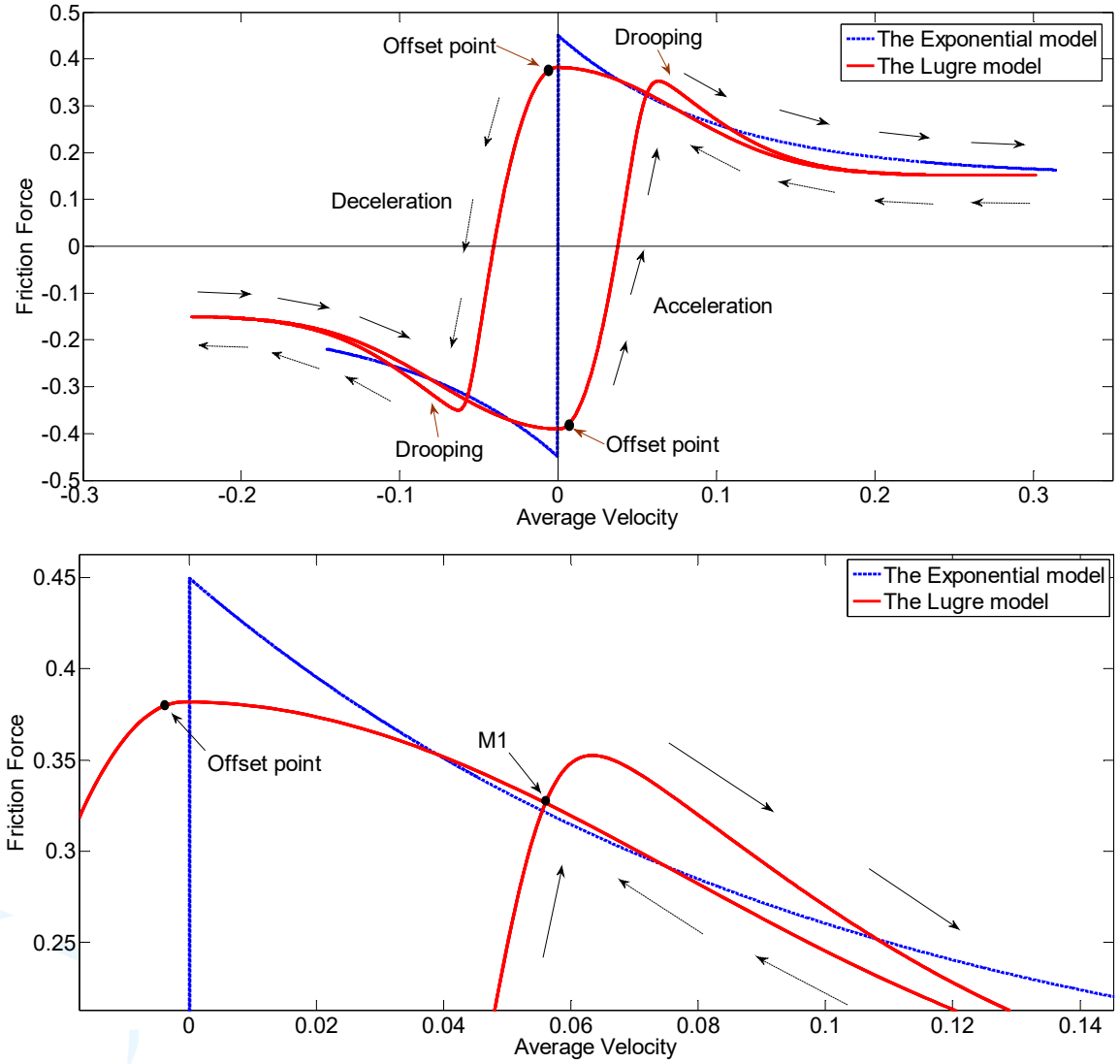
Comparison of the friction-driven response in time coordinate with the LuGre model (red solid lines) and the Exponential model (blue dashed lines), respectively.



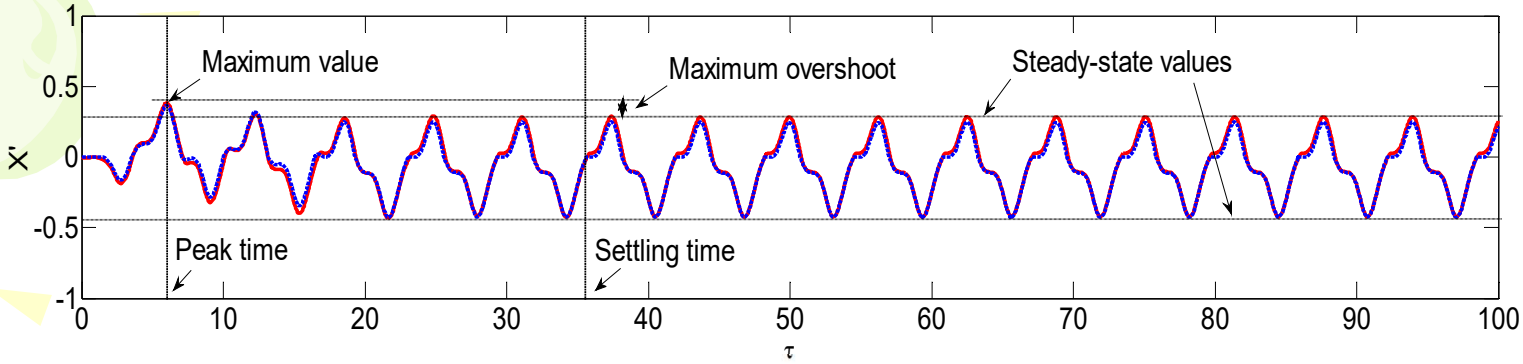
Comparison of the phase portraits of the collocated subsystem for the Exponential model (blue dashed lines) and the LuGre model (red solid lines)



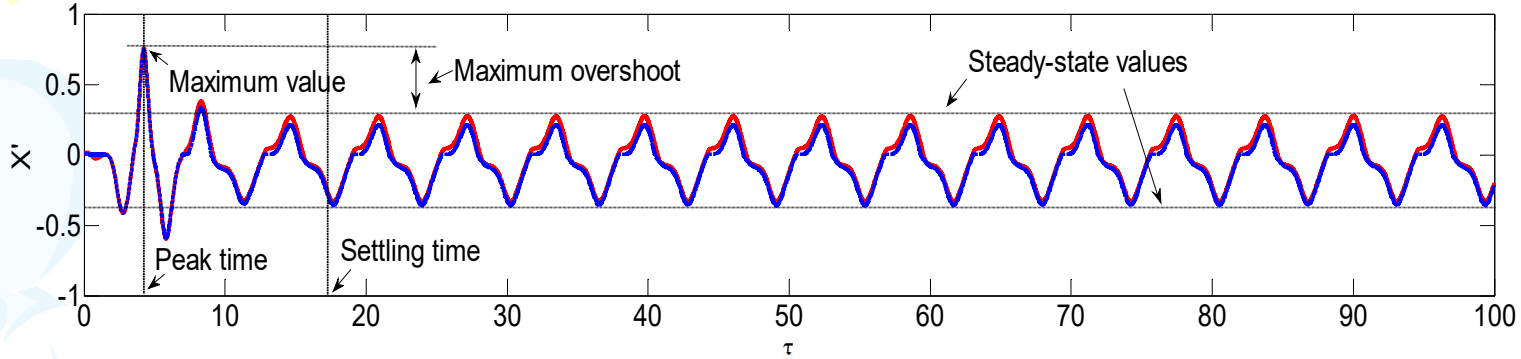
Comparison of the phase portraits of the non-collocated subsystem for the Exponential model (blue dashed lines) and the LuGre model (red solid lines)



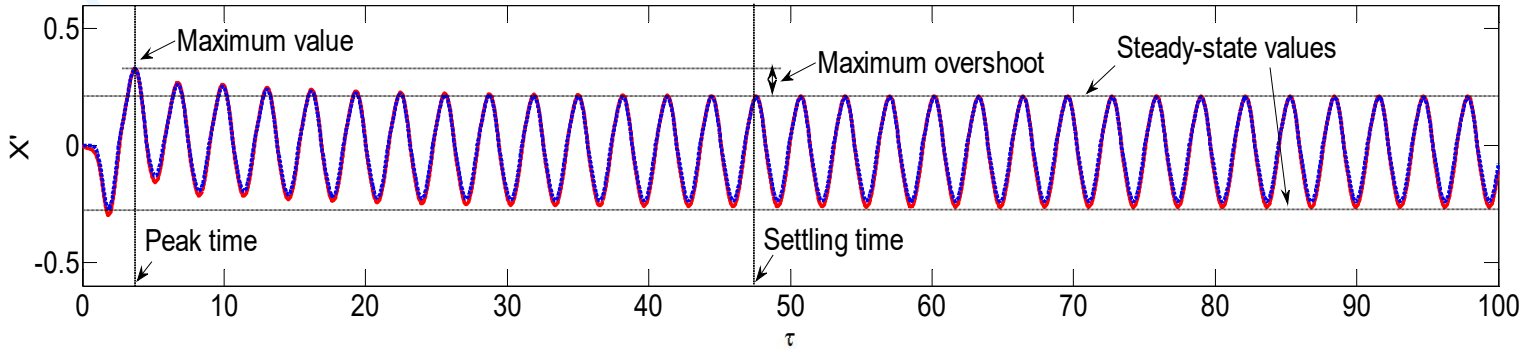
Comparison of the friction curves for the Exponential model (blue dashed lines) and the LuGre model (red solid lines) in (a) and the zoom up in (b) showing the friction characteristics near zero average velocity.



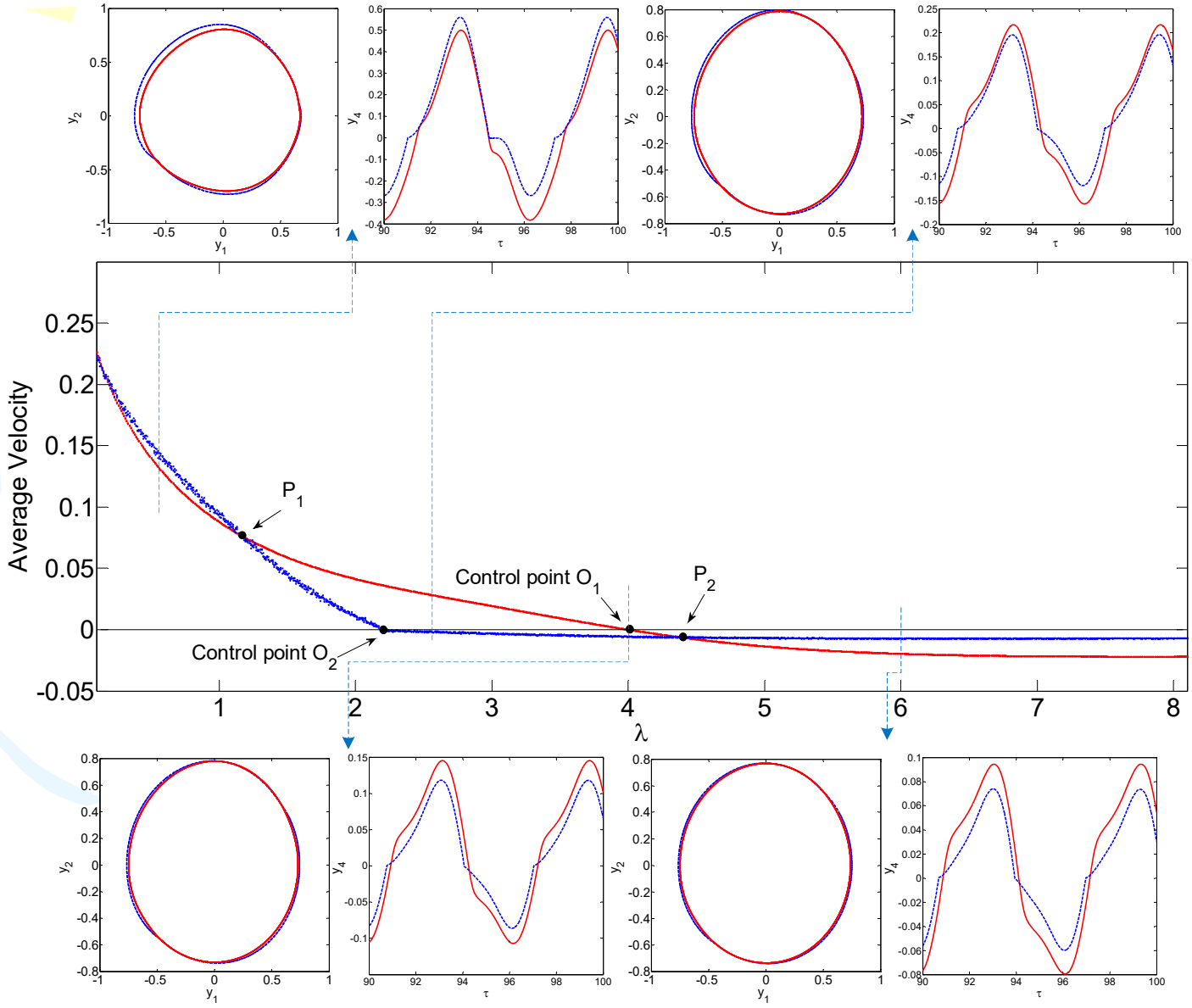
(a) $h = 1.5,\ \omega = 1.0$



(b) $h = 2.5,\ \omega = 1.0$



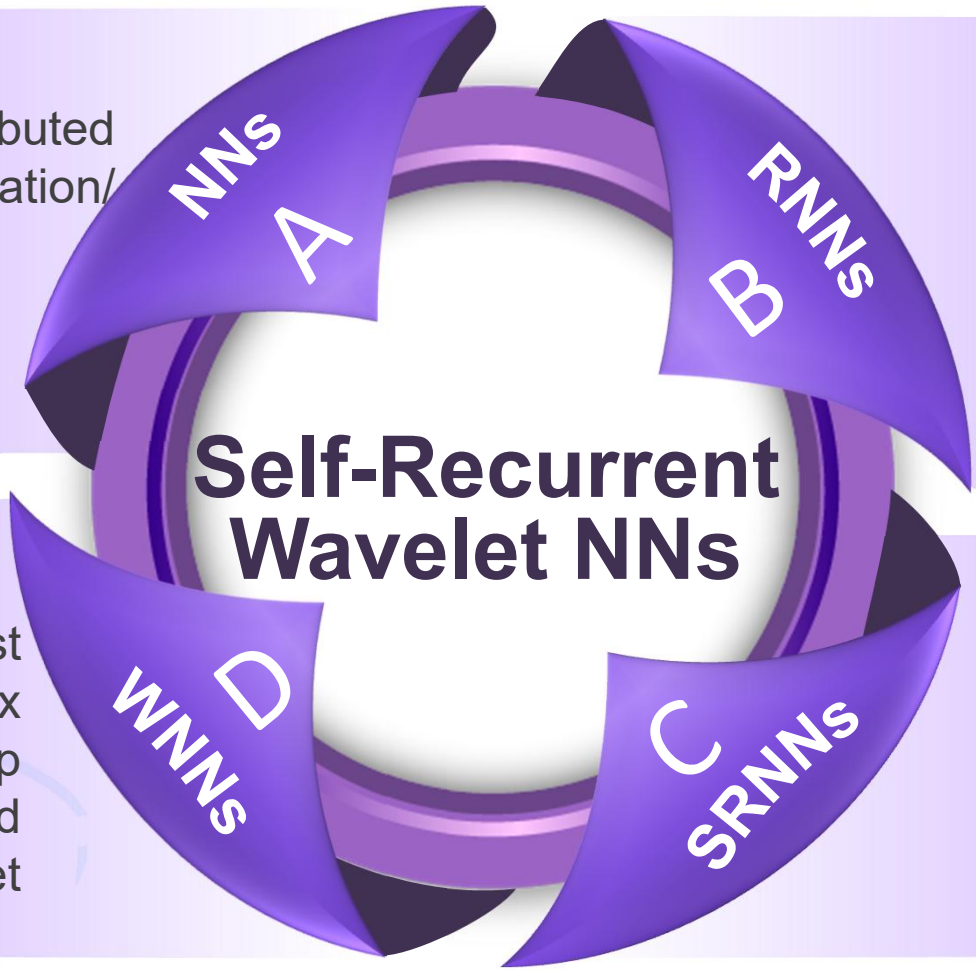
(c) $h = 1.5,\ \omega = 2.0$



Bifurcation analysis

SRWNNs-based robust adaptive control for a class of UUMSs

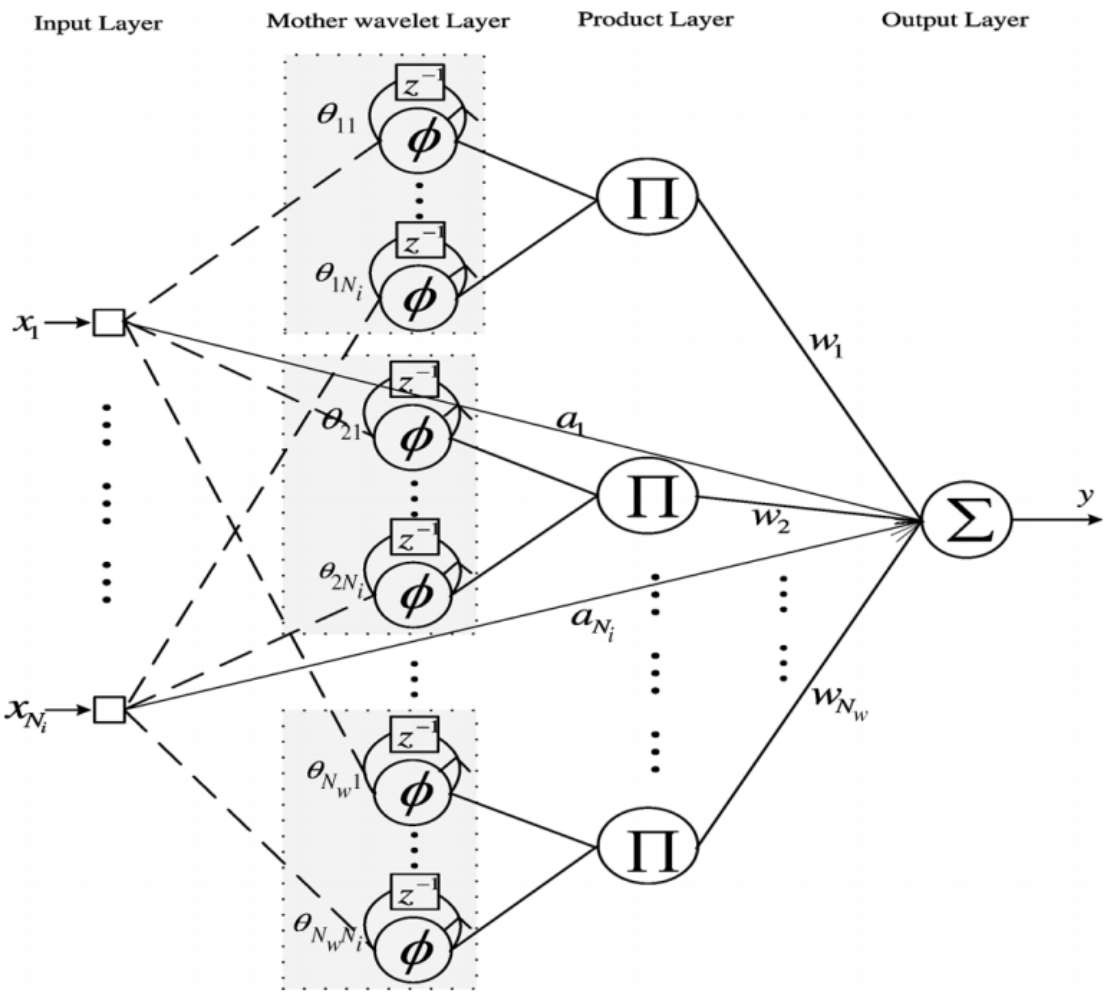
Paralleled and distributed structure, Approximation/ prediction property



Attractor dynamics

Wavelet decomposition, high accuracy, fast learning, complex systems with sharp changes, good convergence, yet static problems

Internal feedback neurons & real-time learning



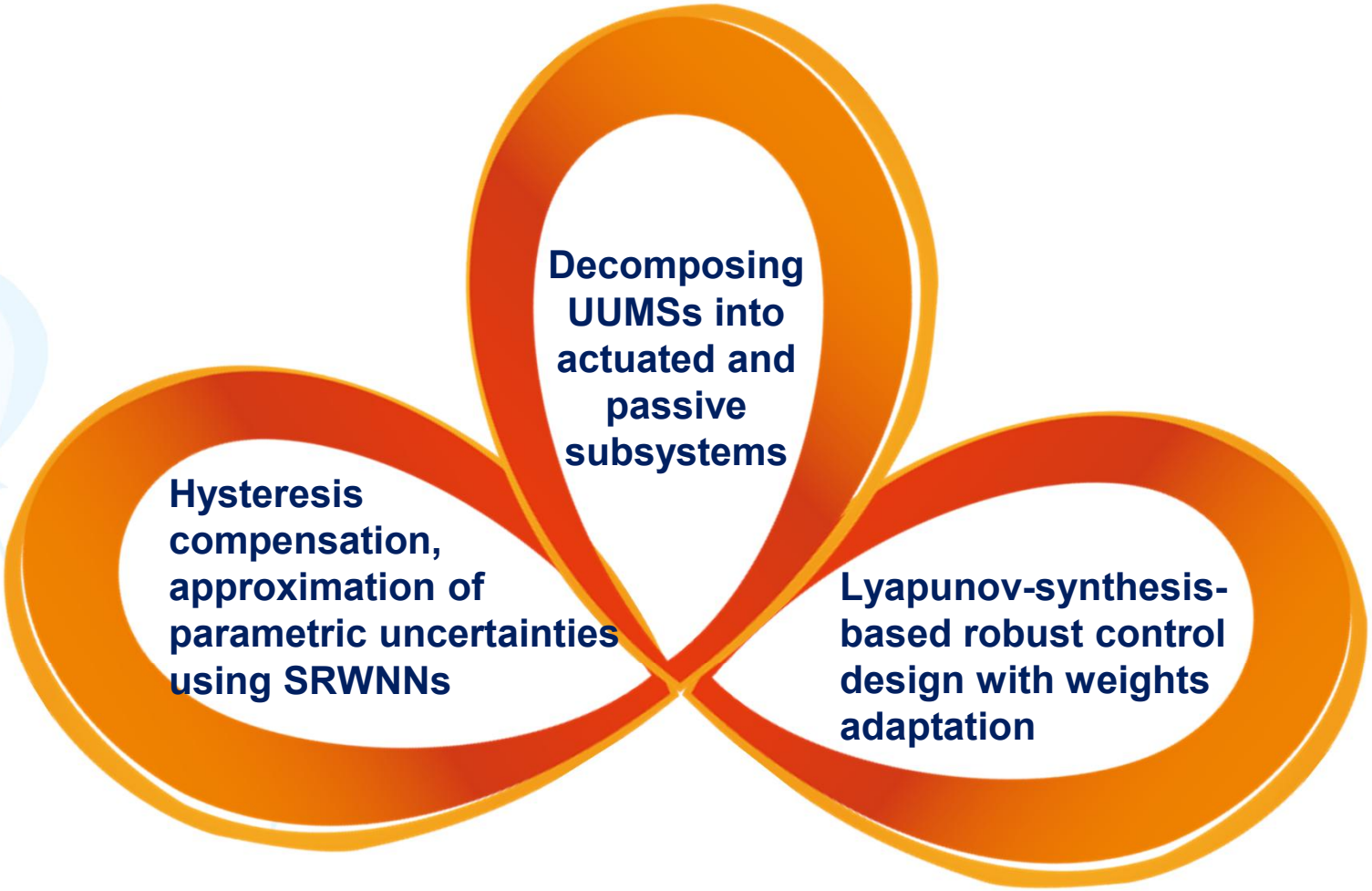
Structure of SRWNN

$$y = \sum_{j=1}^{N_w} w_j \left(\prod_{k=1}^{N_i} \emptyset_{jk}(z_{jk}(N))\right) + \sum_{k=1}^{N_i} a_k x_k(N)$$

$$z_{jk}(N) = (x_k(N) + \emptyset_{jk}(N\text{-}1) \times \theta_{jk} - m_{jk})/d_{jk}$$

$$\emptyset_{jk}(z_{jk}) = -z_{jk} e^{-\left(\frac{1}{2}\right) z_{jk}^2}$$

Conclusions and Future Works



References

[1] P. Liu, H. Yu, and S. Cang, “On periodically pendulum-driven systems for underactuated locomotion: A viscoelastic jointed model,” *the 2015 IEEE International Conference on Automation and Computing*, 2015, pp. 1-6.

[2] P. Liu, H. Yu, and S. Cang, “Geometric techniques for trajectory planning and chaos control of a bio-inspired autogenetic capsule robot,” *the 7th BU Annual Postgraduate Conference*, Bournemouth, 2015.

[3] P. Liu, H. Yu, and S. Cang, “Modelling and control of an elastically joint-actuated cart-pole underactuated system,” *the 2014 IEEE International Conference on Automation and Computing*, 2014, pp. 26–31.

[4] P. Liu, H. Yu, and S. Cang, “Design, modelling and control of a capsule robot with hybrid propulsions for medical inspections and assistances,” the 5th BU Annual Postgraduate Conference, Bournemouth, 2014.

THANK YOU